Earthquake Advisories: Issues for Discussion by NEPEC

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What is an Earthquake Advisory?

- Currently, it is public statement, issued following a moderate earthquake, that informs the public that a larger earthquake, with potential for damage, has a temporarily elevated probability of occurrence
- In California, these statements are issued by OES and include recommended actions

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Earthquake Advisory Issued For San Francisco Bay Area

October 31, 2007

In response to Tuesday evening's magnitude-5.6 earthquake near the junction of the Calaveras and Hayward faults, the following statement was issued by the California Earthquake Prediction Evaluation Council, a panel of scientists chaired by the State Geologist that advises the Director of the Governor's Office of Emergency Services (OES) on the scientific validity of earthquake forecasts and seismic activity in areas where damaging earthquakes have occurred in the past.

"A magnitude 5.6 earthquake occurred at 8:05 Tuesday evening (30 October 2007). The earthquake occurred near the junction of the Calaveras and Hayward faults in the southern San Francisco Bay Area. Both of these faults are known active faults capable of producing large, damaging earthquakes.

"CEPEC believes that this evening's earthquake has significantly increased the probability above the normal level for a damaging earthquake along the Calaveras and/or Hayward faults within the next several days. However, the overall likelihood of such an event is still low. Scientists will be continuing to monitor the situation and advise OES of any changes.

In response to the CEPEC evaluation of this earthquake, OES recommends that residents of the San Francisco Bay region review their family emergency plans, check their emergency supplies, identify the "safe" and "potential danger" spots in each room, remove breakables from locations from which they can fall and cause injury, and stay tuned to the radio or television for further information. OES also recommends that government agencies and businesses review their plans. The "advisory" applies to the following counties: Alameda, Contra Costa, Marin, Monterey, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano and Sonoma.

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CISN California Integrated Seismic Network
California's Partner to the Advanced National Seismic System

CGS USGS OES Caltech UC Berkeley

09/28/2004 - Aftershock Information

Home
Earthquake Info
News & Updates
Products & Services
Who We Are
Calendar
Links & Resources
Contact Us

Like most earthquakes, the recent earthquake is expected to be followed by numerous aftershocks. Aftershocks are additional earth... in the same geographic area. Usually, afters... occasionally an aftershock may be strong er... and may cause additional damage.

Typically, the chance of an earthquake com... is 5-10% in the next 7 days. Of the six histo... have occurred in the Parkfield region, one, ... larger earthquake that ruptured the San And... widespread damage in southern California. ... that insufficient slip has accumulated to allo... probability of that event recurring soon as u... historical Parkfield earthquakes were not fo...

In this unlikely event that a comparable or l... would likely rupture the San Andreas fault ... in southern California. It is unlikely that a la... Andreas fault toward the north (toward the... San Andreas fault is slowly creeping and no... stress for a larger earthquake.

The likelihood of all aftershocks, including ... described above, is greatest during the first ... with time.

- Aftershock warning as of 09/28 at 11...

09/28/2004 Park...
CISN Earthq...

Berkeley Seismological Laboratory — Northern California...
California Integra...
www.c...

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Parkfield 2004 Aftershock Info

Like most earthquakes, the recent earthquake is expected to be followed by numerous aftershocks. Aftershocks are additional earthquakes that occur after the mainshock and in the same geographic area. Usually, aftershocks are smaller than the mainshock, but occasionally an aftershock may be strong enough to be felt widely throughout the area and may cause additional damage.

Typically, the chance of an earthquake comparable to or larger than today's earthquake is 5-10% in the next 7 days. Of the six historical earthquakes of comparable size that have occurred in the Parkfield region, one, in 1857, was followed 9 hours later by a larger earthquake that ruptured the San Andreas fault to the south, and caused widespread damage in southern California. Since that time our measurements indicate that insufficient slip has accumulated to allow that event to repeat and so we judge the probability of that event recurring soon as unlikely and we note that the other five historical Parkfield earthquakes were not followed by a larger earthquake.

In this unlikely event that a comparable or larger event occurs, such an earthquake would likely rupture the San Andreas fault toward the south, and be felt most strongly in southern California. It is unlikely that a larger earthquake will rupture the San Andreas fault toward the north (toward the SF Bay region) because this portion of the San Andreas fault is slowly creeping and not thought to have accumulated sufficient stress for a larger earthquake.

The likelihood of all aftershocks, including the relatively unlikely larger earthquakes described above, is greatest during the first day of aftershocks, and diminishes rapidly with time.

Reasons to issue Earthquake Advisories

- Around half of damaging earthquakes are preceded by foreshocks
- With advance warning, some injuries and loss of life could be prevented, and some emergency measures could be put in place

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Problematic Science Basis for Advisories

- Rigorous foreshock statistics
  - Only possible with adequate data (CA, NV, global subduction zones)
  - Actual CA advisories not followed by mainshocks in 3-5 day window
  - Highest probability is in first hour after mainshock; advisories not issued until hours later
  - Longer warning windows seem unlikely to be useful
    - That is actually a social science question
- No experience base for geodetically-based warnings

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Role of Scientific Community

- Only one of several players needed to implement successful warning plan
- Next two slides describe general paradigm for a warning plan as envisioned by Denis Mileti and Erica Kuligowski…

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WARNING SUBSYSTEMS AND FUNCTIONS

RISK SUBSYSTEM
Natural Environment
Technological
Civil

MANAGEMENT SUBSYSTEM
Interpretation
Decision to Warn
Warning Content
Warning Method & Channel
Response Monitoring
Warning Feedback

DETECTION SUBSYSTEM
Monitoring
Detection
Data Assessment & Analysis
Prediction
Informing

PUBLIC RESPONSE SUBSYSTEM
Interpretation
Confirmation
Response
Warn Others

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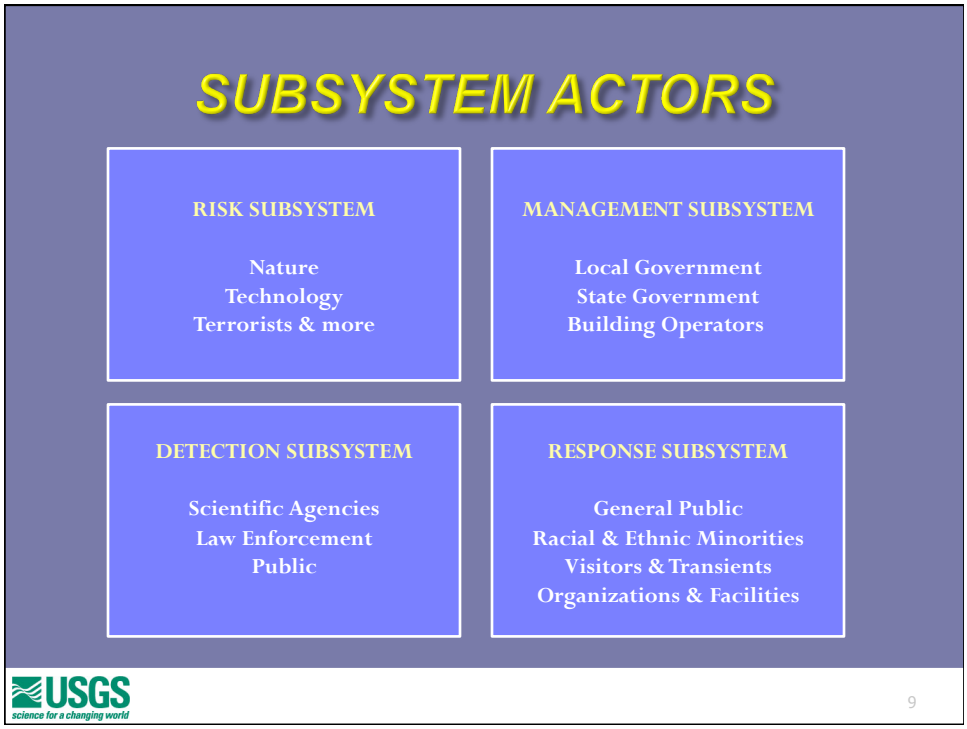
8



Role of Earthquake Science Community:

- Motivate discussion of advisory plans
  - Inform public officials and emergency managers that earthquake science can provide some information about the development of earthquake sequences
  - Work with them to determine how this information would be most useful
- If such a plan is adopted, USGS would need to:
  - Develop realistic plans for implementing it
  - Promote research related to improving advisories
  - Work to keep the public informed

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Science Role is Not:

- To decide advisories are unwise because of potential negative impacts
- Emergency managers and public officials have the option of deciding that

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Social Science Research

- Much research is available on warnings in general (Mileti, others…)
- Additional research could be done that is specifically for earthquake warnings:
  - On responses to California advisories
  - On the 2008 Reno swarm advisory

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Candidates for Advisories

- Cascadia (CA, OR, WA, Canada) has most immediate need
  - California could issue advisory for event M>5; no corresponding plan for OR, WA, or Canada
  - Canada could issue advisory for a slow slip event
- Other candidates:
  - California - add geodesy-based advisories
  - Nevada
  - Utah
  - Alaska
  - Hawaii
  - New Madrid
  - Other?

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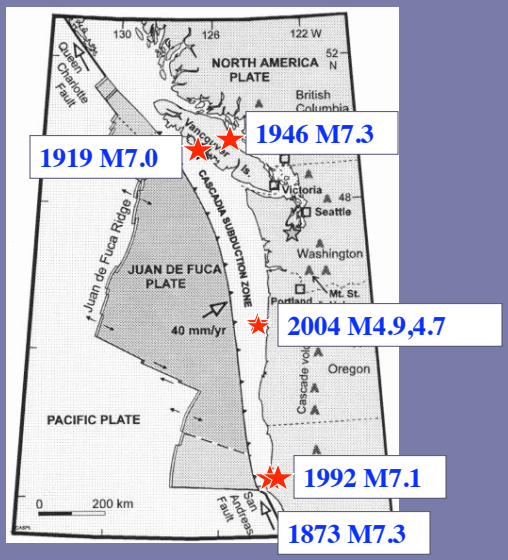
Cascadia Subduction Interface Seismicity



Pacific Geoscience Center, updated by ER

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Cascadia Megathrust Sequences

- Megathrust rupture will not be a single event
  - M9 (NSHMP 67% weight) will have aftershocks, likely including M8 earthquakes months/years later
  - Several events M8-8.7 (NSHMP 33% weight), temporal evolution of sequence unknown
- Indicators that Cascadia event sizes vary:
  - Turbidite studies (Goldfinger et al.) indicate more events, shorter recurrence intervals (220 years) southern Oregon
  - Nelson et al. (various paleo indicators) find evidence for shorter recurrence intervals in southern Oregon
  - Tremor-slip events in southern Oregon recur more often and seem to represent less slip than northern Cascadia ETS events
- Will now be able to monitor sequence evolution with GPS and strainmeters

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Cascadia Policy Challenges

- 3 states, 2 countries involved
  - CA far ahead in knowledge, awareness of earthquakes
- Far-flung research community monitors seismicity, GPS, tremor, strain
- Offshore seismicity monitored by universities, not part of networks
- Warnings could potentially arise from
  - Potential foreshocks
  - Accelerated aseismic slip

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Aseismic Deformation

- Aseismic deformation that differs from "business as usual"
  - Updip, ie, closer to locked zone
  - Much larger
- Microfossil evidence suggests possible longer-term (years) pre-seismic coastal subsidence
- Tokai experiment is a possible model

Much work to define basis for possible advisories

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Steps to implement advisories

- Within USGS, create outline of plan
  - Draft statements
  - Procedure for identifying events and alerting scientists
    - Seismic and aseismic
    - Commit to adequate resources
  - Decisions about who will play role of CEPEC outside CA
- Meet with public officials and emergency managers to present plan and refine it
  - In CA, OES issues the advisories
  - Who should do it for, e.g., Cascadia?
- Implement plan and maintain readiness

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Simple ideas for discussion

- Implement aftershock forecasts outside of California
- Include a statement that a larger earthquake is possible (already done in CA)
- Include information consistent with the National Seismic Hazard Maps:
  - Largest event expected on same or nearby faults
  - NSHMP-agreed recurrence interval, and elapsed time since the last event
  - Highlight expected effects if such an event were to occur

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Need for a workshop

- USGS hould prepare draft plan for presentation
- Convene public officials, and emergency managers, and scientists who are interested in working with these issues
- FEMA funded?

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USGS Postdoc Opportunity

- Cascadia Subduction Zone Seismic and Aseismic Slip Scenarios: Implications for Public Policy
  - studies of earthquake dynamic or static stress triggering in subduction zones
  - foreshock probabilities (e.g., updating the global synthesis of Reasenberg, 1999)
  - forecasting Cascadia post-seismic slip and its hypothetical implications for evolution of a Cascadia megathrust earthquake sequence
  - risk communication and social implications of possible "Earthquake Advisory" announcements
  - relationship of slow slip events to major earthquakes(e.g., Mazzotti and Adams, 2004)
  - optimal utilization of seismic data to rapidly constrain depths and focal mechanisms of earthquakes offshore Cascadia (e.g., Trehu et al., 2008)
  - studying the feasibility of implementing a Tokai-like warning scheme for Cascadia.

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Applications due Nov 12, 2008